## IN THE SPECIFICATION:

Please replace the list of inventors with the following corrected list of inventors:

Bijan Sayyarrodsari, Eric Hartman, Celso Axelrud, and K[[i]]adir Liano

Please insert the following paragraph at page 1, line 3, per 37 CFR 1.78(a)(5):

This application claims benefit of priority to U.S. provisional application Serial No. 60/431,821, titled "System and Method of Adaptive Control of Processes With Varying Dynamics," filed December 9, 2002, whose inventors were Bijan Sayyarrodsari, Eric Hartman, Celso Axelrud, and Kadir Liano.

Please insert the following Section Header just before paragraph [008]:

SUMMARY

Please replace paragraph [0017] with the following replacement paragraph:

**[0017]** In the application of the present invention to a particle accelerator, controlled variables such as but not limited to varying magnetic field strength, shape, location and/or orientation are controlled by adjusting corrector magnets and/or quadr[[a]]upole magnets to manipulate particle beam positions within the accelerator so as to achieve more efficient interactions between particles.

Please replace paragraph [0028] with the following replacement paragraph:

**[0028]** The present invention provides a powerful tool for the analysis of the nonlinear relationship between the manipulated/disturbance variables and the controlled variables such as those at the Stanford [[Position]] Positron Electron Asymmetric Ring (SPEAR). Tuning of the control variables can benefit from this analysis. SLAC performs and supports world-class research in high-energy physics, particle astrophysics and disciplines using synchrotron radiation. To achieve this it is necessary to provide accelerators, detectors, instrumentation, and support for national and international research programs in particle physics and scientific disciplines that use synchrotron radiation. The present invention plays a key role in advances within the art of accelerators, and accelerator-related technologies and devices specifically and generally to all advanced modeling and control of operating processes – particularly those that exhibit sever nonlinear behavior that vary over time.

Please replace paragraph [0035] with the following replacement paragraph:

**[0035]** Because a spread-out beam gives fewer collisions than a narrowly focused one, the electron and positron bunches are sent into damping rings 33 (electrons to north, positrons to south). These are small storage rings located on either side of the main accelerator. As the bunches circulate in damping rings 33, electrons 14 lose energy by synchrotron radiation and are reaccelerated each time they pass through a cavity fed with electric and magnetic fields. The synchrotron radiation decreases the motion in any direction, while the cavity reaccelerates only those in the desired direction. Thus, the

bunch of electrons or positrons becomes increasingly parallel in motion as the radiation "damps out" motion in the unwanted directions. The bunches are then returned to accelerator 18 to gain more energy as travel within it. Further focusing is achieved with a quadr[[a]]upole magnet or [[connector]] corrector magnet 16 in beamlines. Focusing here is achieved in one plane while defocusing occurs in the other.

Please replace paragraph [0037] with the following replacement paragraph:

**[0037]** Inside accelerator 18, the microwaves from the klystrons set up currents that cause oscillating electric fields pointing along accelerator 18 as well as oscillating magnetic fields in a circle around the accelerator pipe. Electrons and positrons at the end of the linear accelerator 10 enter the Beam Switch Yard (BSY) 34. Here the electrons are diverted in different directions by powerful dipole magnets 35 or [[connector]] corrector magnets 35 and travel into storage rings 36, such as SPEAR, or into other experimental facilities or beamlines 38. To efficiently operate accelerator 10 operators constantly monitor all aspects of it.

Please replace paragraph [0046] with the following replacement paragraph:

**[0046]** EPICS includes a set of software tools and applications which provide a software infrastructure with which to operate devices within the particle accelerators such as connector or quadr[[a]]upole magnets or other like devices used to influence particle trajectories. EPICS represents in this embodiment a distributed control system

comprising numerous computers, networked together to allow communication between them and to provide control and feedback of the various parts of the device from a central room, or remotely over a network such as the internet.

Please replace paragraph [0056] with the following replacement paragraph:

**[0056]** This distributed control system [[provides]] implements the 'standard model' paradigm. This control system[[s]] allows modularity, scalability, robustness, and high speed in hardware and software, yet remains largely vendor and hardware-independent.

Please replace paragraph [0069] with the following replacement paragraph:

**[0069]** The absence of a systematic way for handling varying process dynamics forces application engineers to devote significant energy and time so that the variations in process dynamics does not result in serious degradation of the controller performance. The present invention extends the existing formulations such that variations in process dynamics can be properly considered. This may result in improved input/output controller (IOC) performance as well as expanded operating conditions. The derivation of the proposed algorithm is based on the following general representation for the dynamics of the process as a nonlinear, possibly time-varying difference equation:

$$Y_K = F(u_k, u_{k-1}, \ldots, u_{k-M}, y_{k-1}, \ldots y_{k-N}) \qquad [[(7)]]\underline{(5)}$$

where $u_k$ is the vector of input variables affecting the process (i.e., both manipulated and disturbance variable inputs), $y_k$ is the vector of measured outputs, and $F$ is a potentially time-varying nonlinear vector function.

In one embodiment, the present invention proposes the following perturbation model to locally approximate Equation (5):

$$\delta y_k = \sum_{i=1}^{N} \alpha_i(u_k, u_{k-1},\ldots,u_{k-M}, y_{k-1},\ldots, y_{k-N})\delta y_{k-1} + \sum_{i=1}^{M} \beta_i(u_k, u_{k-1},\ldots,u_{k-M}, y_{k-1},\ldots, y_{k-N})\delta y_{k-1} \tag{6}$$

where the coefficients $\alpha(.)$ and $\beta(.)$ can be defined as:

$$\alpha_i(u_k, u_{k-1},\ldots,u_{k-M}, y_{k-1},\ldots, y_{k-N}) = \frac{\partial F}{\partial y_{k-i}} \tag{7}$$

and

$$\beta_i(u_k, u_{k-1},\ldots,u_{k-M}, y_{k-1},\ldots, y_{k-N}) = \frac{\partial F}{\partial u_{k-i}} \tag{8}$$

are functions of present and past inputs/outputs of the system. The methodology presented in this invention is applicable for higher order local approximations of the nonlinear function F. Also, as mentioned earlier, for a given state-space representation of a nonlinear parameter-varying system, an equivalent input/output model with the representation of Equation (5) can be constructed in a variety of ways known to experts in the field. Hence, the methodology presented here encompasses systems described in state-space as well. The approximation strategy captured by Figure 7 is directly applicable to any functional mapping from an input space to output space, and hence the approach in this invention is directly applicable to state space description of the linear processes with varying dynamics.

Please replace paragraph [0081] with the following replacement paragraph:

**[0081]** To approximate the difference equation during process's transition from initial operation point to its final operation point, one possibility is to vary the parameters affinely between their two terminal values. This choice is for ease of computation, and the application of any other approximation for the parameter values in between (including but not limited to higher order polynomials, sigmoid-type function, and tangent hyperbolic function) as is known to those skilled in the art may also be employed. To highlight the generality of the approach in this invention, the present invention may follow affine approximation of the functional dependency of parameters on input/output values is described here. Assume that p is a dynamic parameter of the system/process such as time constant, gain, damping, etc. Parameter $p$ is a component of the FPM parameters 95 in Figure 7. Also assume that $p = f(u_k, u_{k-1}, \ldots, u_{k-M}, y_{k-1}, \ldots, y_{k-N})$, where $f$ is an appropriate mapping. Note that with the assumption of steady state behavior at the two ends of the transition $u_k = u_{k-1} = \ldots = u_{k-M}$ and $y_{k-1} = y_{k-2} = \ldots = y_{k-N}$. An affine approximation for this parameter can be defined as follows:

$$[[\ p(u_k, u_{k-1}, y_{k-1}, y_{k-2}) = p(u_{init}, y_{init}) + p_u\left(\frac{\partial p}{\partial u}\right)_{init}(u_k - u_{init}) + p_y\left(\frac{\partial p}{\partial u}\right)_{init}(y_k - y_{init}) \quad (13)]]$$

$$\underline{p(u_k, u_{k-1}, y_{k-1}, y_{k-2}) = p(u_{init}, y_{init}) + p_u\left(\frac{\partial p}{\partial u}\right)_{init}(u_k - u_{init}) + p_y\left(\frac{\partial p}{\partial y}\right)_{init}(y_k - y_{init}) \quad (13)}$$

where for simplicity $M$=$N$=2 is assumed.

When state space description of the process is available $p$ may be a function of state as well. The methodology is applicable regardless of the functional dependency of $p$.

Please replace paragraph [0088] with the following replacement paragraph:

**[0088]** The results from the modeling effort on the collected data on SPEAR II are summarized in FIGURES 8, 9, and 10. A quick look at the relevant data captured in the course of one experiment where three manipulated variables (MVs) were intentionally moved in the course of the experiments: two corrector magnets and one quadr[[a]]upole magnet. The reading of Beam Position Monitors (BPMs) is recorded as the controlled variables (CVs) or output of this experiment.

Please replace paragraph [0089] with the following replacement paragraph:

**[0089]** Screen capture 100 of the input/output variables from the test data is provided in FIGURE 8. Note that the $x$ and $y$ reading of one of the BPMs are chosen as CVs and the MVs are the ones mentioned earlier, the tag name for which is clearly indicated in the screen capture. FIGURE 8 evidences the clear correlation between the MVs with the BPM. Another screen analytic is provided in FIGURE 9 gives a better screenshot 110 of the variation in variables.

Please replace paragraph [0091] with the following replacement paragraph:

**[0091]** FIGURE [[10]] 11 displays one such input/output relationship for the SPEAR Equipment at SLAC. This figure clearly shows the nonlinear input/output relationship in the above-mentioned model.

Please replace paragraph [0093] with the following replacement paragraph:

**[0093]** In summary, the present invention provides a method for controlling nonlinear control problems in operating processes like a particle accelerator. The invention utilizes modeling tools to identify variable inputs and controlled variables associated with the process, wherein at least one variable input is a manipulated variable input. The modeling tools are further operable to determine relationships between the variable inputs and controlled variables. A control system that provides inputs to and acts on inputs from the modeling tools tunes one or more manipulated variables to achieve a desired controlled variable, which in the case of a particle accelerator may be realized as a more efficient collision.

Please replace paragraph [0094] with the following replacement paragraph:

**[0094]** FIGURE 12 provides another illustration of the relationship of the process 200 and the controller 202 and more importantly the relationship of the models 204, 206 and 208 within the controller 202 to the control of the process 200. A typical process has a variety of variable inputs $u(t)$ some of these variables may be manipulated variable inputs 210 and some may be measured disturbance variables 212 and some may be unmeasured

disturbance variables 214. A process 200 also typically has a plurality of variable outputs. Some are measurable and some are not. Some may be measurable in real-time 220 and some may not 222. Typically, a control system's objective is to control one of these process variable outputs. [[t]]This variable is [[can be]] called the [[control variable or]] controlled variable. Additionally, to the controller the process variable outputs may be considered one of the variable inputs to the controller or controller variable inputs 223. Typically but not necessarily, a control system uses a distributed control system (DCS) 230 to manage the interactions between the controller 202 and the process 200 - as illustrated in the embodiment in FIGURE 12. In the embodiment shown the controller includes a steady state model 204 which can be a parameterized physical model of the process. This model can receive external input 205 comprised of the desired controlled variable values. This may or may not come from the operator or user (not shown) of the process/control system 202. Additionally the embodiment illustrates a steady state parameter model 206 that maps the variable inputs *u* to the variable output(s) *y* in the steady state model. Further, the embodiment illustrates a variable dynamics model 208 which maps the variable inputs *u* to the parameters *p* of the parameterized physical model ~~(steady state model)~~ of the process. In one embodiment of the invention empirical modeling tools, in this case NNs, are used for the Steady State parameter model and the variable dynamics parameter models. Based on input received from the process these models provide information to the dynamic controller 232 which can be optimized by the optimizer 234. The Optimizer is capable of receiving optimizer constraints 236 which may possibly receive partial or possibly total modification from an external source 238 which may or may not be the operator or user (not shown) of the process 200 or control

system 202. Inputs 205 and 208 may come from sources other than the operator or user of the control system 202. The dynamic controller 232 provides the information to the DCS 230 which [[sends]] provides setpoints for the manipulated variable inputs 240 which is the output of the controller 240.